DIGITAL RESOURCES AND MATHEMATICS TEACHERS PROFESSIONAL DEVELOPMENT AT UNIVERSITY

Ghislaine Gueudet

CREAD, IUFM Bretagne UBO

For university mathematics as for other levels, a profusion of digital resources is available for teachers. This evolution impacts the teacher's practices, and contributes to teachers' professional development. Retaining here a focus on the interactions between teachers and resources, I study the use of digital resources for the teaching of mathematics at university, and how this use articulates with teachers' professional knowledge and its evolution. I also investigate the consequences of digital resources for teachers' collective work. I consider these issues, drawing on a case study concerning a mathematics lecturer working with computer science students.

Keywords: collaboration, digital resources, documents, teacher development, university teachers' professional knowledge

TEACHER RESOURCES AND PROFESSIONAL DEVELOPMENT, IN THE UNIVERSITY CONTEXT

The profusion of digital resources for the teaching of mathematics is a well-known fact. Its consequences for teacher professional development have been, and are studied in a number of research works (Gueudet, Pepin & Trouche, 2012), in the context of primary and secondary school. This issue has not been studied at university yet.

We retain here the theoretical perspective of the documentational approach (Gueudet & Trouche, 2009). This approach considers that teachers interact with resources: textbooks, websites, software; but also students productions, discussions with colleagues. Teachers combine resources, design their own resources, set them up in class, modify them: we name this process the teachers' documentation work. It holds a central place, in teachers' professional activity. Interestingly, a recent work (Mesa & Griffiths, 2012) considers textbooks mediation of teaching at university, in mathematics. The authors identify several types of mediation, and observe that the use of textbooks by lecturers changes over time. The perspective adopted here is very similar, and textbooks are part of our study, which considers more generally all teaching resources. Drawing on the instrumental approach (Rabardel, 1995) we consider that teachers, along their interactions with resources, for a given teaching objective, develop a document: a mixed entity, associating resources and utilization schemes of these resources. This process is called documentational geneses. For the sake of brevity, we do not give here a detailed description of schemes. We retain that documents encompass resources and, in particular, professional knowledge, of different kinds: subject matter knowledge, pedagogical knowledge, but also, and this is essential in our study, pedagogical content knowledge, if we refer to Shulman's (1986) categories. The documents of a given teacher constitute a structured set, his/her documentation system. This documentation system associates a resource system, and professional knowledge.

Teachers' professional knowledge evolves, along the use of resources. For example, using a given software can lead to evolutions of the teacher's knowledge, concerning this software, but more generally also concerning mathematics and their learning by students. Thus teachers' documentation work is central, for professional development; moreover, the interactions between teachers and digital resources are nowadays an essential aspect of this documentation work. We propose here to study teacher documentation at university, with a focus on the role of digital resources.

Our study takes place in France, where teacher education, at university level, is very limited. In a few French universities, experimental groups associate researchers in mathematics education and mathematicians, that can be considered as "*clinical partnerships* between researchers and practitioners" (Wagner, 1997). More commonly, short training programs are proposed to university teachers, to discover a new software in particular; but there is no in-service training program concerning pedagogical issues. In this context, I claim that teacher documentation work is the principal source of teacher professional development at university. I study here two main questions, related to this issue:

- How do university mathematics lecturers use digital resources, to reach their pedagogical objectives? How does this use articulate with their professional knowledge, and its evolution?
- Which evolutions of mathematics lecturers' work at university can arise from the use of digital resources, in particular concerning collective work?

My aim in this paper is not to provide complete answer to these general questions, but to propose possible answers, and to open directions for further research, through the study of a particular case.

STUDYING DOCUMENTATION WORK: METHODS

Studying documentation work means to consider long-term processes, that happen in several places: the classrooms, but also the teacher's office, or even his/her home. Interviewing the teacher, asking her/him about her/his use of resources and the evolutions of this use is essential, but not enough. An essential methodological tool, associated with documentation, is the collection of the teacher's resources (Gueudet, Pepin & Trouche, 2012): extract of the books, the websites she/he uses; the students' sheets he/she writes; e-mails exchanged with colleagues etc. During the interview, the researcher asks to investigate the teacher's computer, to see his/her cupboards, and all possible places where material resources are kept. This complete data collection process corresponds to an ethnographic approach, which requires an important mutual commitment of the teacher and the researcher. Naturally, the conditions of the research work do not always permit to reach such a commitment.

The data used here have been collected in the context of a European Research project, Hy-Sup (Burton *et al.*, 2011), aiming at studying the use at university of distant platforms. In the context of this project, I followed in 2010-2011 two mathematics lecturers, who used in particular a Moodle platform for their teaching. I focus here on the case of one of these two lecturers, Peter.

I collected his resources, and met him for an interview that has been recorded and transcribed. This interview comprised several parts, concerning respectively: his working context and use of resources in general, digital resources in particular; a detailed presentation of his use of digital resources in the context of a precise course – he retained his linear algebra course -; the evolutions he retained of his own practice, linked with the use of digital resources.

The interview is firstly analysed by noting all the resources, and the agents (students, colleagues etc.) mentioned. Then I retain the teacher's comments about the use of each resource, in particular: his aims, for the use of a given resource; his expression of beliefs about the role of these resources in his teaching of mathematics; the mention of evolutions. All these elements are confronted with the main resources collected: for example, when the teacher declares using a textbook, the content of the book is confronted with the students' sheets designed by using this book.

A CASE STUDY

Peter has a PhD, about partial differential equations, obtained in 2001. Since 2001, he teaches at university; he obtained a position as full-time lecturer, and stopped his research activity. Peter teaches mathematics at a Universitary Technological Institute, specialized in computer science, in France. These institutes, inserted in Universities, offer a two-years training with professional objectives. They deliver professional diploma after these two years; nevertheless, nowadays more than 80% of the successful students continue their studies afterwards, to graduate or even to obtain a Master degree.

The teaching of mathematics, in Peter's institute, is organised in several courses, each of them concerning a given mathematical topic (for example: “linear algebra”). Each course lasts 40 hours: 5 hours a week, over 8 weeks. One hour is the lecture; two hours are a paper-and-pencil tutorial; two hours take place in the computer laboratory, using a computer algebra system (CAS, in what follows) – namely Scilab.

All the material used for a course is available for the students on a Moodle platform. The students also upload their own productions with Scilab on this platform, for correction by the lecturers.

Peter's resource system: an overview

For the preparation of his courses, Peter uses classical mathematics textbooks, written for students of this level (for example, Ramis, Deschamps & Odoux, 1979). These were the textbooks he used himself as a student in mathematics. He also uses books about the history of mathematics (Hauchecorne & Surrateau, 1999).

Peter appreciates the use of technology – he used different software himself as a student, and developed this use as a lecturer. He can be considered as a technology enthusiast (Monaghan, 2004). He uses various software: Scilab, the CAS used in the technological institute courses; LaTeX, to compose his students' sheets, and his courses; different software for composing web pages, and wikis; and Moodle. He also visits many websites: websites associated with given software, personal websites of colleagues, Wikipedia etc. Peter is an experienced lecturer; the courses he produced during the previous years are now central resources, in his documentation work.

His professional webpage (figure 1) gathers many of these resources, produced during previous years. The texts of his courses, exercises lists (ordinary mathematics exercises, or exercises for working on the computer), exam texts. It also proposes technical notices, about Scilab, or about non-mathematical tools, like wikis.

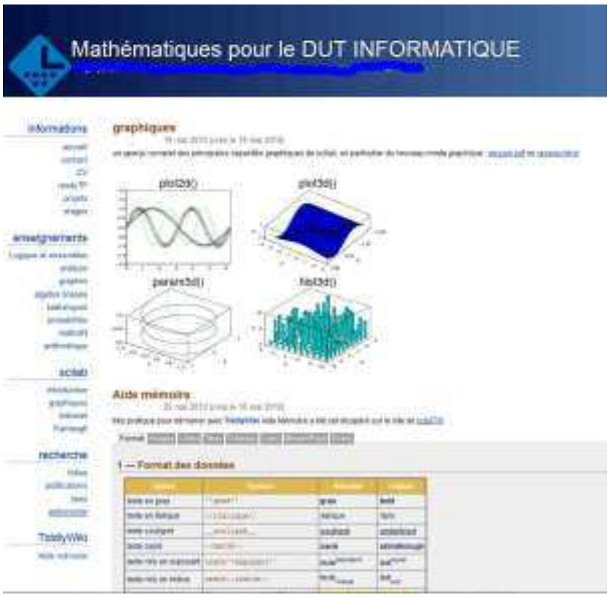

Figure 1. Peter's professional webpage.

Mathematics for computer science students, and use of digital resources

One difficulty, emphasized several times by Peter in his interview, is that his students are not specialized in mathematics. He mentions mainly two kinds of consequences of this fact: the students have limited mathematical skills; and they are not interested in theory, only in mathematics as a tool for computer science.

P: We adapt the content, because it is very complicated, for such students […] They are students in computer science, mathematics is not their central subject.[1]

Another difficulty of his teaching context, that he emphasizes, is the heterogeneity of his students' skills in mathematics. He has indeed students from several origins. Some of them come directly from secondary school; amongst those, some were specialized in mathematics (which means receiving 8 hours of mathematics courses each week in grade 12), and others not (which means only 4 hours of maths each week in grade 12, with a very technical content). Other students have spent one year at university before, possibly in mathematics major. Moreover, the students' aims can also be very different, between obtaining the two-year diploma, or trying to go further, to obtain a master degree. “We have a very broad spectrum of students”, declares Peter in his interview, describing all these possibilities.

Peter himself was a student in mathematics, specialized in a very theoretical research subject in partial differential equations. During his PhD, he gave courses at university for mathematics majors. Discovering this new teaching context, at the technological institute, was a important change for him, which raised professional questions. His answers to the interview, and the analysis of his resource system, indicate that he developed several kinds of solutions, linked with digital resources.

Scilab, supporting the learning of mathematics

Scilab holds a central place in Peter's resource system. One reason for this is that it contributes to answer to the professional questions mentioned above. Peter (together with his colleagues, at the technological institute) considers it as very important, for raising the students motivation, and helping their comprehension.

P: Programming the topics taught in maths gives a practical aspect […] when they implement Gauss method, they appropriate it.

Peter considers that programming a mathematical method with a software helps to understand the mathematics. Research works about the use of CAS to teach mathematics, at the beginning of university (e.g. Weller *et al.,* 2003, Gyöngyösi *et al.*, 2011) indicate that such possibilities indeed exist, under certain conditions, since the software can also constitute a difficulty. Another important aspect, not mentioned in the interview but evidenced by Peter's resources (figure 1), is that he extensively uses the possibilities of visualization offered by Scilab.

Scilab also intervenes in the management of students' heterogeneity. Firstly, almost all the first year students discover Scilab, the differences existing in mathematics do not exist about this software. Moreover, Peter composes texts, for the Scilab sessions, which comprise a common, minimum basis; and many complements. Thus

1 Our translation.

the high-achieving students have something to do, working by themselves on a computer; at the same time the lecturer can support students having more difficulties.

P: I see that in the computer lab session, a weak student, not motivated, and a good motivated student, their work is completely different, a 1 to 3 ratio.

Here the text proposed by the lecturer, and the computer with Scilab are combined resources, for the management of students' heterogeneity.

I asked Peter, about his use of Moodle for the same objective (he could, for example, propose to some of the students an out-of-class work). He does not use it for this objective, because he considers that most of the work in mathematics must be done in class, in particular for the students who have difficulties.

Raising students' motivation by using mathematics for computer science

Peter tries to present mathematics as a useful tool for computer science, in order to raise the students' interest. For example, the text of his linear algebra course finishes with the example of Google searching process: the notion of PageRank, and its links with vector spaces, and eigenvectors (figure 2).

En 1996 Larry Page et Sergey Brin, deux étudiants en doctorat à l'université de Stanford, eurent l'idée d'une nouvelle définition du PageRank : *"la pertinence d'une page web est proportionnelle à la somme des pertinence des pages qui pointent vers elle"*. Cette définition peut se traduire par un système d'équation linéaires dont les inconnues sont les pertinence des pages $x_k > 0, k = 1, 2, \ldots$ et le coefficient de proportionnalité λ :

$$\forall i, \quad \sum_{j \in P_i} x_j = \lambda x_i, \quad P_i = \{j | \text{ la page } j \text{ pointe vers la page } i\} \qquad (1)$$

En d'autre terme : *les PageRank forment un vecteur propre (de coordonnées positives) associé à une valeur propre (non-nulle) d'une matrice représentant les liens entre les pages web.*

Figure 2. Extract of Peter's linear algebra course, Google definition of PageRank[2]

Peter also proposes to his students to implement well-known algorithms – he calls it "real applications". A "real application", for him, is for example the RSA algorithm[3], in cryptography; the students implement it, in the context of his arithmetic course.

2 In 1996 Larry Page and Sergey Brin, two Stanford University PhD students, had an idea for a new definition of the PageRank: "the relevance of a web page is proportional to the sum of the relevance of webpages offering links to it". This definition corresponds to a system of linear equations, whose unknowns are the relevance of pages $x_k>0$, and the coefficient λ. […] In other words: the PageRank constitutes an eigenvector (with positive coordinates) associated with an eigenvalue (non-zero) of a matrix representing the links between web pages.

Digital resources and evolving collective dimensions of teachers' work at university

Peter often works with his mathematics colleagues at the technological institute. For each course (e.g. “linear algebra”), a lecturer is responsible of the course. This lecturer gives the lecture; he/she builds the content of the lecture -the corresponding file is available on this lecturer's webpage, and on Moodle, for his/her colleagues and for the students. The texts of the tutorials and of Scilab sessions are usually collectively composed. Sometimes Peter also works with computer science colleagues, to propose and follow “students' projects” (for second year students; the students have to design a software, over six months).

Peter learned by himself to use various technologies, ranging from Scilab to Moodle. The university offers some technical training sessions, but they were proposed too late for Peter who trained himself before! He reads the software notices; but the most useful tool for him is always the “Frequently Asked Questions” pages. We consider this as a collective dimension: Peter's knowledge evolved, by reading the answers to questions raised by colleagues on these websites.

As mentioned above, on his webpage he proposes, for students and colleagues, technical notices, about the use of different software: Scilab, but also wiki tools. He works with his mathematics colleagues, in particular, for the use of new digital means.

P: My colleagues have started to use Scorn, to program multiple choice questionnaires... We can insert them in Moodle, for the assessment.

Peter's colleagues have learned to use a software, for building online tests in Moodle. Peter himself did not learn it yet, but he can use the questionnaires. Here the collective work is needed, because of technical difficulties, in discovering new software. Moreover, it will probably lead to a change in the students' assessment: instead of written tests, they will fill in online tests on the Moodle platform.

DISCUSSION

Initial research questions, and the case of Peter

Our first set of questions concerned the use of digital resources by mathematics lecturers to reach their pedagogical objectives, and its articulation with professional knowledge.

Peter's resource system comprises a large range of digital resources of different kinds. This means that these digital resources belong to documents, developed by Peter, which associate sets of resources and professional knowledge.

3 RSA stands for Rivest, Shamir and Adleman, who first publicly described this coding algorithm in 1977.

Scilab (considered here as a resource) is involved in several documents, developed by Peter, with the objective to teach university mathematics to computer science students. Along his use of Scilab, Peter developed professional knowledge, about the possible use of a CAS to support the learning of university mathematics, for students who have a low interest in theoretical issues. Working with CAS permits an approach of the mathematical concepts through practical tasks (Gyöngyösi *et al.*, 2011); this professional knowledge is part of the document he developed.

Scilab is also involved in another document, developed for an objective of management of the students' heterogeneity. Other resources intervene in this document: the computer lab naturally, and also the texts composed by Peter, with a core content, designed for all the students, and complements for gifted students. Professional knowledge, intervening in this document, is formulated by Peter in his interview as: “the students have very different skills, some of them can be very fast”; “if a high-achieving student finishes the task to early, he/she will disturb the other students in their work”. As noticed above, he does not use Moodle, for the same objective, because he considers useless to propose distant work to students who have difficulties. He developed this knowledge along his observation of students at the technological institute. A direct consequence is that Moodle is not inserted, for Peter, in a document for the management of heterogeneity.

In fact Moodle is mostly used as a place where students can find information about the courses schedule, and can upload their productions (for downloading, Peter's webpage already offers most of the files that the students can find on Moodle). We consider that Moodle is not really integrated yet in Peter's resource system. This situation can naturally evolve, in particular if Peter develops his use of the Scorn questionnaires designed by his colleagues.

Besides all these digital resources, surprisingly Peter's resource system comprises a mathematics textbook, published in 1979 – the textbook that his own lecturers used, when he was a student. This textbook is for him the reference, for the mathematical content of his courses; he uses it to build his courses texts, and complements it with “cultural information”, about the life of mathematicians, or the actuality of computer science. It leads to an important gap, between a theoretical course, and the practical applications proposed to the students. The use of these “old” resources, in some cases, can contribute to explain why university mathematics teaching can seem to be “congealed”- resources also yield a kind of inertia (this has been evidenced, for assessment texts at university, by Lebaud, 2009).

Our second set of questions concerned the evolutions of mathematics lecturers' work, with a focus on collaboration.

Peter works with his mathematics colleagues, and digital resources play an important part in this collaboration. The files designed for their teaching are exchanged, via e-mail, or using the webpages, or Moodle. Moreover, since the university does not propose teacher training, about new software, a mathematics lecturer who has learned how to use a particular software writes information, suggestions, offers texts on his/her webpage, for colleagues.

University teachers' resources and documentation: directions for research

The case of Peter is certainly very special. He is a technology enthusiast, teaching mathematics to computer science students; under these conditions, the importance of digital resources in his system is not surprising. Moreover, Peter has no research activity; this fact certainly impacts his resource system. Nevertheless, Peter's case informs us more generally about the use of resources by lecturers at university, and suggests directions for further research. We retain here questions about teaching resources, digital resources in particular, and about collective teachers' work.

University lecturers, like all teachers, use many resources to design their teaching. They use in particular textbooks; the work of Mesa & Griffiths (2012) identifies needs for further research on this topic, in particular about how teachers' use and students' use articulate, how textbooks articulate with lecture notes, how textbooks use evolves over time. All these issues are essential, I add here a fourth direction: How does teachers' textbook use articulate with their use of digital resources?

These digital resources deserve a specific study. Many researchers have already studied the use, at university, of specific software for mathematics, like CAS, or visualization software. Nevertheless, it has mostly been considered in terms of students' learning. The integration of mathematical software by university lecturers, the professional development associated with it, has not been investigated yet. Moreover, the use by lecturers of digital resources like online exercises, distant platforms, and virtual learning environments is also a new, interesting direction. These resources open possibilities, in particular for assisting diversely able students with a diversity of tasks. Is this potential effectively used by the teachers, and if not, which kind of teacher education could foster and support this use?

Concerning collaborative work, in the case of France we can claim that lecturers' work is more collective at university than, for example, at secondary school. Lecturers have to work together, when a lecture is given to a large number of students, who will then follow tutorials in sub-groups. Teachers giving tutorials have to know the content of the lecture, to coordinate for the content of the tutorials etc. They also generally write the exam texts together. Digital resources have fostered these aspects of collaborative work: the lecturers can indeed easily exchange files, via e-mail, or on webpages. Which are the consequences, for teacher knowledge, of this collaborative work? Do university lecturers, working together, develop similar beliefs, ideas about their teaching?

Investigating the interactions between teachers and resources, at university, requires specific studies. These interactions are a major factor, for teachers’ professional development, and studying them could enlighten specific features of university teacher's professional knowledge. Such research works could contribute to the design of resources, for the teaching of mathematics at university, and to propositions, for teacher education.

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